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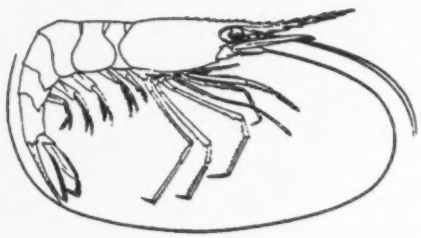
REFERENCE POINTS CONSISTENT WITH THE PRECAUTIONARY APPROACH FOR NORTHERN SHRIMP IN THE ESTUARY AND GULF OF ST. LAWRENCE



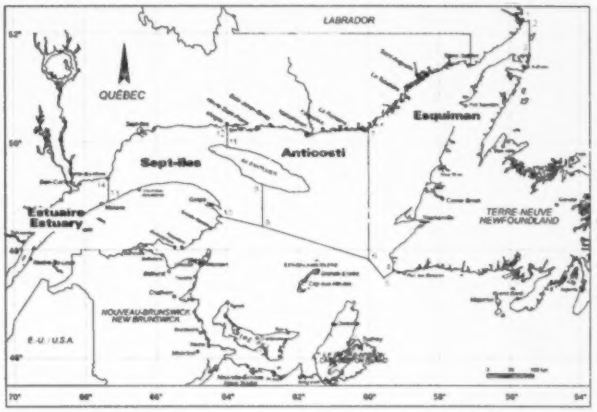


Figure 1. Shrimp fishing areas in the Estuary and Gulf of St. Lawrence.

Context

Canada, as signatory to the United Nations Agreement on Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNASF) has committed to using the Precautionary Approach (PA) in managing stocks. In 2009, DFO completed a policy document entitled "A fishery decision-making framework incorporating the Precautionary Approach" which explains in detail how the precautionary approach will be put into practice. In compliance with the PA, fishery management plans should include harvest strategies that incorporate a limit reference point that defines the critical / cautious zone boundary and an upper stock reference point that delimits the cautious / healthy zone boundary on the stock status axis, and a Removal Reference that defines the maximum removal rate in the healthy zone.

A national workshop was held in November 2008 on the development of precautionary approach frameworks for Canadian shrimp fisheries (DFO 2008). The establishment of limit reference points and upper stock reference points delineating the healthy, cautious and critical stock status zones was discussed at the meeting. Provisional reference points based on a female abundance indicator were proposed for the Gulf of St. Lawrence fishery. A peer review held on November 2, 2011 examined new reference points based on the main indicator used to assess resource status since the 2009 fishing season. This indicator is based on the abundance of males and females estimated from the commercial fishery and research survey. These new reference points will be used to define a precautionary approach for managing of shrimp stocks in the Gulf.

Canada

SUMMARY

- The main indicator of stock status is calculated from the male (recruitment to the female component) and female indices (spawning stock) obtained from the summer fishery (number per unit effort) and research survey (abundance). The adoption of the main indicator is used to replicate the informal method that was used to determine the status of the resource and recommend a TAC.

- Stocks increased from a relatively low abundance level in the mid-1980s and mid-1990s due to productive year-classes. In the first case, predator abundance was high and probably had a major impact on the maximum abundance level that stocks may have reached. In the second case, abundant cohorts were produced when predator abundance was decreasing. Thus, it appears that the spawning stock was sufficient to produce abundant cohorts which had a noticeable impact on stock condition. The stock status for these low abundance levels from which they have increased represents the limit reference point (LRP). The LRP for the Estuary fishing area is 0.65, for Sept-Îles, 0.53, for Anticosti, 0.60 and Esquiman, 0.45. Nevertheless, stock behaviour in the critical zone is uncertain since it has never been observed during the studied period.

- The production of very abundant year-classes has allowed stocks to increase again in the early 2000s when predation mortality was most likely low. However, stock status has gradually decreased in recent years and exploitation rate indices have increased. It is thus uncertain whether the abundance levels observed since 2003 can be maintained.

- The 1996-2002 period appears to represent a stable period during which catches proved to be sustainable. The average stock status for this productive and stable period represents a biomass approximation based on the maximum sustainable yield. The upper reference point (USR) value, in compliance with the fishery decision-making framework for incorporating the precautionary approach, could be equal to 80% of this value. The USR for the Estuary fishing area could be 1.12, for Sept-Îles, 1.33, for Anticosti, 1.18 and Esquiman, 1.34. However, the USR level was only observed in the absence of predators. If the biomasses of the large groundfish species return to the high values historically observed, it may be necessary to review the USR since it is not certain whether the shrimp stocks could reach abundance levels as high under maximum predation conditions.

- A target reference point (TRP) could be adopted based on socio-economic objectives. The mean indicator values between 1996 and 2002 could be used as a TRP. The TRP for the Estuary fishing area could be 1.40, for Sept-Îles, 1.66, for Anticosti, 1.48 and Esquiman, 1.68.

INTRODUCTION

Species Biology

The northern shrimp, *Pandalus borealis*, is a protandrous hermaphrodite species. In other words, individuals first reach sexual maturity as males, then change sex and become females. This feature of the life cycle is very important for the development of harvest strategies since larger individuals which are targeted by the fishery are almost exclusively female.

In the Estuary and Gulf of St. Lawrence, shrimp larvae hatch in the spring, in April or May and remain pelagic for several months. At the end of the summer, post-larvae adopt suprabenthic behaviour. Juveniles reach male sexual maturity during their second year. Spawning occurs in the fall and males may spawn two or three years prior to changing sex, which occurs in winter at age 4 or 5 at around 21 mm carapace length. Newly transformed females are easily recognized in spring and summer commercial catches as they have retained some male sexual characteristics. These females are called primiparous females and spawn the very next fall (September or October) after the sex change. Females carry their fertilized eggs under their abdomen during the incubation period which lasts about 8 months and the larvae hatch the following spring. Spawning females that survive reproduction are recognizable to those who have never spawned and are called multiparous females. In fact, primiparous and multiparous females can be distinguished by morphological characteristics (sternal spines) that disappear in the prenuptial moult. Females can spawn at least twice and the estimated longevity of Estuary and Gulf shrimp is about seven years.

Shrimp make annual migrations that are related to reproduction. In late fall and early winter, egg-bearing females undertake a migration and are concentrated in the shallower areas of their distribution range. In the spring, they gather on favourable sites for releasing larvae, while males remain scattered throughout the area. Females moult after larvae hatches and they disperse over the deeper parts of the area. Therefore, female catchability varies according to the season. Harvesters know how to take advantage of these egg-bearing female aggregations in spring and late fall to obtain high yields. Catch rates stabilize in late spring when larvae have hatched and harvesters disperse over the area. In summer, catches are composed of males and females and catch rates are relatively stable.

Description of the Fishery

The number of active shrimp fishery licences in the Estuary and the Gulf in 2010 was about 150. Harvesters come from five provinces and seven First Nations. Fishery management measures include the imposition of a minimum mesh size (40 mm) and, since 1993, the compulsory use of the Nordmore grate, which significantly reduces groundfish by-catches. Shrimpers must also keep a log book, have their catches weighed at dockside and agree to have an observer on board upon request by the Department (5% coverage). The fishery opens on April 1st and closes on December 31st. The fishery has been managed by TAC since 1982, and the traditional fishermen have had individual quotas since the mid-1990s.

Landings of northern shrimp in the Estuary and Gulf of St. Lawrence have risen gradually since the fishery began. Landings rose from approximately 1,000 tons to 7,500 tons between the early and late 1970s, and to 15,000 tons by the late 1980s. They remained mostly stable between 1990 and 1995, and gradually increased to reach over 23,000 tons. Landings have totalled 35,000 tons on average since 2004.

ANALYSIS

Resource status indicator

The stock assessment is descriptive and focuses on the review of indicators from the commercial fishery and research survey (DFO 2011). These two data sources are independent and provide indicator estimates that are considered good indices of shrimp abundance. As the information from these two sources is complete and reliable, it was decided to use them equally (with the same weight) in developing the main stock status indicator. However, given that catchability varies over a fishing season, fishery index estimates were restricted to summer (June, July and August) during which the catchability of males and females is assumed to be constant. In addition, since northern shrimp change sex, it is important to consider both males (recruitment to the female component) and females (spawning stock).

The main stock status indicator is calculated from the indices of males and females obtained from the summer fishery (number per unit effort) and the research survey (abundance) (Figure 2).

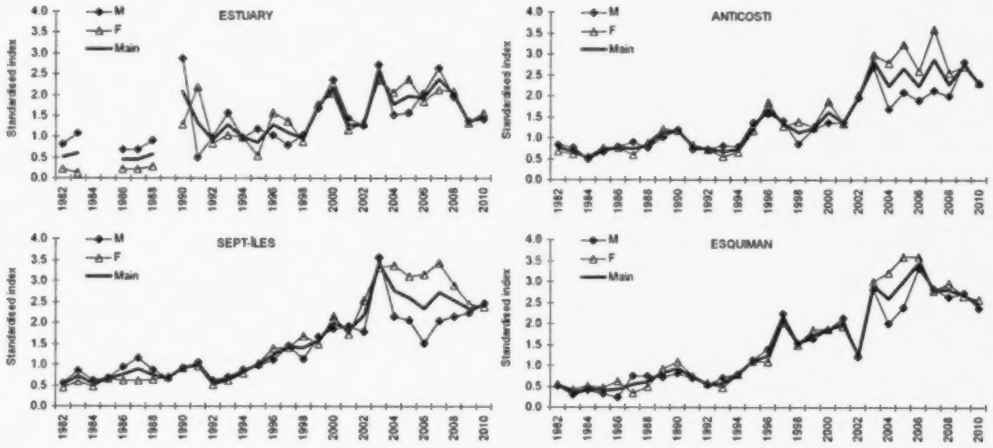


Figure 2. Standardized indices of males and females and main stock status indicator.

In order to combine the indices, each is first standardized with respect to the 1990-1999 period (annual value of the index divided by the 1990-1999 geometric mean). The integrated index by sex is obtained by calculating the average between the fishery index and the survey index. The stock status indicator is the average of the integrated indices by sex. The 1980 data are derived exclusively from the commercial fishery. The research survey began in 1990 and it is difficult to find independent fishery data for the 1980s. However, given the consistency between the fishery data and survey data, it is assumed that the use of a single data source from 1982 to 1989 does not cause significant bias in terms of stock status trajectory.

The use of the main indicator leads to conclusions similar to those obtained with the informal method which was used to assess stock status and make TAC recommendations. In fact, an assessment of the relationship between TACs and landings and stock status indicators shows

that for all stocks, the TAC adopted after the scientific recommendation and landings for a given season are directly proportionate to the stock status indicator from the previous year (Figure 3).

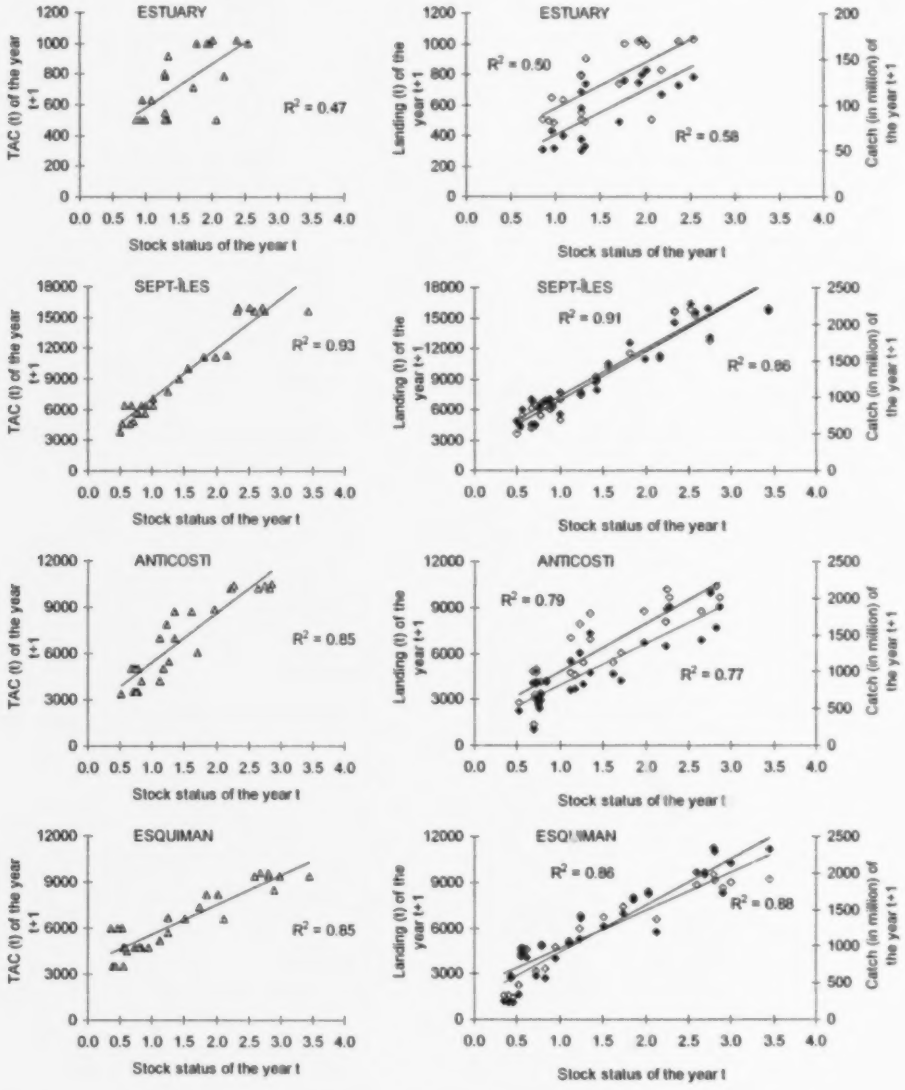

ESTUARY
TAC (t) of the year (t+1
R² = 0.47
Stock status of the year t
ESTUARY
Landing (t) of the year (t+1
Catch (in million) of the year (t+1
R² = 0.50
R² = 0.58
Stock status of the year t
SEPT-ÎLES
TAC (t) of the year (t+1
R² = 0.93
Stock status of the year t
SEPT-ÎLES
Landing (t) of the year (t+1
Catch (in million) of the year (t+1
R² = 0.91
R² = 0.86
Stock status of the year t
ANTICOSTI
TAC (t) of the year (t+1
R² = 0.85
Stock status of the year t
ANTICOSTI
Landing (t) of the year (t+1
Catch (in million) of the year (t+1
R² = 0.79
R² = 0.77
Stock status of the year t
ESQUIMAN
TAC (t) of the year (t+1
R² = 0.85
Stock status of the year t
ESQUIMAN
Landing (t) of the year (t+1
Catch (in million) of the year (t+1
R² = 0.86
R² = 0.88
Stock status of the year t

Figure 3. Relationship between the main stock status indicator in a given year and the TACs adopted the following year after scientific recommendation (left) as well as commercial fishery results (right: landings in weight, open symbols and catches in numbers, closed symbols). 1982-2010 period except Estuary, 1990-2010.

Therefore, the use of the main indicator for determining stock status does not lead to any major change in the multiple indicator approach used until recently and maintains the interpretation that was made of each stock's trajectory. It will be used as a reference for determining stock status classification zones.

Reference points

The reference points were established by following DFO guidelines from the document entitled: *A fishery decision-making framework incorporating the precautionary approach* (DFO 2009). Stock status classification zones require determining a limit reference point (LRP) that delimits the critical / cautious zone boundary and an upper stock reference point (USR) that delimits the cautious / healthy zone boundary. The LRP represents the stock status below which serious harm is occurring to the stock. The USR is the stock level threshold below which removals must be progressively reduced in order to avoid reaching the LRP. A third reference point, the target reference point (TRP), can be determined according to broader objectives related to resource productivity or socio-economic factors.

Limit Reference Point

Establishing a limit reference point (LRP) is based entirely on biological considerations and aims at preventing irreversible damage. Stocks increased twice from a relatively low abundance level during the study period in the mid-1980s and mid-1990s due to the production of abundant year-classes. In the first case, predator abundance was high and likely had a major impact on the maximum abundance level that stocks could reach. In the second case, abundant cohorts were produced when predator abundance was decreasing. Thus, it appears that even at these low abundance levels, the spawning stock was sufficient to produce abundant cohorts that had a detectable impact stock condition. The stock status corresponding to these low abundance levels from which they were able to increase, represents the LRP. The LRP value is equal to the average of the minimum indicator of the two periods in the early 1980s and 1990s (Figure 4):

	Estuary	Sept-Iles	Anticosti	Esquiman
Years when the indicator was at a minimum	1986 & 1995	1982 & 1992	1984 & 1993	1983 & 1992
LRP	0,65	0,53	0,60	0,45

It is difficult to assess the contribution of the parent stock to recruitment success for the study period. For example, spring conditions when larvae hatch are likely to have a decisive impact on larval survival. The recovery potential of a spawning stock below the LRP is uncertain.

Proposals for the Upper Stock Reference Point and Target Reference Point

The upper stock reference point (USR) and the target reference point (TRP) are in principle determined by fishery management who must consider consultations with industry stakeholders as well as advice from scientists. The stock status trajectory shows that stocks increased three times during the study period. The last two increase periods occurred while predation mortality was likely low. These two periods are characterized by the recruitment of very abundant year-classes that allowed stocks to increase. However, stock status has gradually decreased since about 2007 and exploitation rate indices have increased (DFO 2011). Thus, it is uncertain whether the abundance levels observed since 2003 can be maintained.

However, the 1996-2002 period appears to represent a stable period during which catches proved to be sustainable. The average stock status for this productive and stable period (1996-2002) represents a biomass approximation based on the maximum sustainable yield. The USR

value is 80% of this value. The TRP should be higher than the USR and could correspond to the average stock status for the 1996-2002 period (Figure 4):

	Estuary	Sept-Iles	Anticosti	Esquiman
USR	1,12	1,33	1,18	1,34
TRP	1,40	1,66	1,48	1,68

The cautious zone situated between the LRP and the USR must be large enough to provide time for fishery management to adopt effective management measures for allowing the stock to respond to these measures.

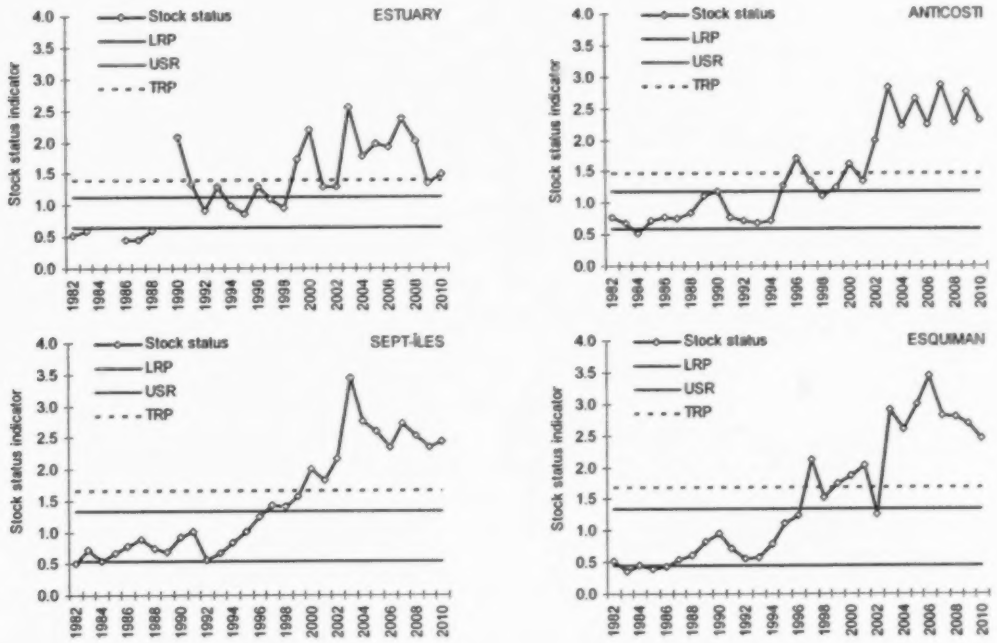


Figure 4. Reference points delimiting the three stock status classification zones.

Shrimp stock dynamics are rapid and marked changes in abundance are possible. However, the average absolute differences between the main indicator values for periods of 2-3 successive years do not exceed the cautious zone range for all the stocks. In general, the greatest differences were observed when the stocks were in the healthy zone, especially after 2003.

Sources of Uncertainty

The allocation of supplementary stations in the Estuary shallow waters beginning with the 2008 survey had a very important impact on the catches of males and females in the Estuary fishing area. The results obtained after a few surveys conducted with this extended area indicate that the abundance in the Estuary area is much greater than that previously estimated and that the exploitation rate index is much lower. The reference points for the Estuary area were based on survey data covering the bottom at depths greater than 183 m (100 fathoms) between 1990 and

2010. Reference points should be reviewed when the survey series with the extended area helps identify with certainty stock abundance and biomass trends.

CONCLUSIONS AND ADVICE

Reference points were determined from the best information available based on the main stock status indicator. Since northern shrimp change sex, it is important to consider both males (recruitment to the female component) and females (spawning stock) in determining the stock status indicator. The LRP is the minimum level of abundance at which stocks were able to increase even in the presence of predators. However, stock behaviour in the critical zone (abundance lower than the LRP) is uncertain because this level of abundance has not been observed during the period used to determine the reference points. It is proposed to position the USR at a level that determines a sufficiently large cautious zone to allow stocks to respond to management measures that may be implemented. However, the USR value corresponds to stock abundances observed in the absence of predators. If the biomasses of the large groundfish species return to the high values historically observed, it may be necessary to review the USR since it is not certain whether the shrimp stocks could reach abundance levels as high under maximum predation conditions. Finally, it is suggested to establish a TRP at a level higher than the USR because that could allow the implementation of management measures before stocks reach the cautious zone.

SOURCES OF INFORMATION

This scientific advice arises from the regional scientific advisory meeting held on November 2, 2011 on the «Precautionary approach reference points and Total Allowable Catch (TAC) adjustments rules for the Northern Gulf of St. Lawrence shrimp (*Pandalus borealis*) Stocks» of Fisheries and Oceans Canadian Science Advisory Secretariat. Any other publication arising from that process will be published when available on the site of the Canadian Secretariat of DFO Science sector at the following address: http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm

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